METHOD FOR JOINING LARGE SUBSTRATES

Background of the Invention

1. Field of the Invention

This invention is related to joining semiconductor substrates. More specifically, the present invention provides a method for joining or coupling together large substrates.

2. Description of the Prior Art

A patentability investigation was conducted and the following U.S. Patents were discovered: U.S. Patent No. 5,376,403 to Capote et al.; U.S. Patent No. 5,128,746 to Pennisi et al.; U.S. Patent No. 5,232,532 to Hori; U.S. Patent No. 5,157,828 to Coques et al.; U.S. Patent No. 5,187,123 to Yoshida et al.; U.S. Patent No. 5,839,188 to Pommer; and U.S. Patent No. 5,842,273 to Schor.

U.S. Patent No. 5,376,403 to Capote et al. discloses electrically conductive compositions which contain metal and solder in addition to polymer forming constituents. A technique is described for eliminating voids in bonding a chip to a flexible substrate. A flexible pad or paper is connected to the underside of the flexible substrate, which will deform during bonding and allow air to flow out of the liquid adhesive before it cures and hardens. The adhesive used to bond the chip to the flexible substrate is liquid or paste (not bonding film or sheet) and the objective is air bubble elimination during bonding.

U.S. Patent No. 5,128,746 to Pennisi et al. teaches a flux containing polymer forming composition. The flux forming constituent is disclosed as an acid selected from the group consisting of abietic acid, adipic acid, ascorbic acid acrylic and, citric acid, and malic acid.

U.S. Patent No. 5,232,532 to Hori describes a technique for eliminating voids in bonding of a chip to a flexible substrate. The goal is to use flexible pad or paper underneath the flexible substrate, which will deform during bonding and allow air to flow out of the liquid adhesive before it cures and hardens.

U.S. Patent No. 5,127,828 to Coques et al. describes use of an adhesive loop between a substrate and a support so that a partial vacuum may be applied to the space between the substrate and the support. The objective is to have uniform squeezing of adhesive and therefore uniform spacing between the substrate and the support after the adhesive is cured.

U.S. Patent No. 5,187,123 to Yoshida et al. describes a void free adhesive layer in bonding of a semiconductor device to a lead frame. The main area of adhesive application is the back side of the die. There is no metal connection between the semiconductor device and the lead frame. The adhesive is applied in liquid or paste form in several pre-arranged spots, so as to prevent formation of voids during semiconductor device attachment onto a lead frame.

U.S. Patent No. 5,839,188 to Pommer discloses the use of non-conductive particles (i.e., "gauge" particles) to provide a uniform gap or separation between two or more substrates, and the use of conductive pastes of copper post/tin to form an electrical interconnection.

U.S. Patent No. 5,842,273 to Schor discloses the use of a conductive adhesive to from an electrical connection between substrates. The adhesive is an elastomeric thermoset with conductive particles, flakes, etc. No solder is used. Electrical connection is primarily through metal contact.

Conventional underfill process, such as that disclosed in the foregoing prior art, for flip chip to substrate jointing is limited to very small joining areas (typically 1-inch by 1-inch area or less). Substrate buildup is expensive. Therefore, what is needed and what has been invented is an economical method for establishing Z-connection between two or more large area substrates through a two-step tack lamination and final lamination process.

Summary of the Invention

The present inventors provides a method for producing an assembly of substrates comprising dispensing a liquid polymeric material between a conducting surface on a first substantially planar substrate and a conducting surface on a second substantially planar substrate. The liquid polymeric material is preferably disposed inwardly from the edges of the first substrate and the second substrate; The method further includes pressing the liquid polymeric material between the first substrate and the second substrate so that the liquid polymeric flows towards the edges of the first substrate and the second substrate; and curing the liquid polymeric material. The conducting surface on the first substrate is placed in contact with the conducting surface on the second substrate after pressing the liquid polymeric material between the first substrate and the second substrate. In another embodiment of the invention the liquid polymeric material is dispensed on dies present on the first or second substrate. Preferably at least one of the substrates has a planar surface area of at least 36 sq. inches, such as a dimension of from about 6 inches to about 6 inches.

The conducting surface of one of the planar substrates includes a solder bump which may or may not have a solder material fluxing agent. The liquid polymeric material comprises from about 15% by weight to about 70% by weight of a polymeric resin, from about 15% by weight to about 70% by weight of a curing agent, and from about 0.10% by weight to about 20% by weight of a polymer fluxing agent. The polymer fluxing agent comprises a beta phenylacid and/or a beta phenylhydroxyacid. The beta phenylacid is selected from the group consisting of beta phenylacetic acid, beta phenylacrylic acid, beta phenylcrotonic acid, and mixtures thereof.

The present invention further provides a polymeric composition comprising from about 15% by weight to about 70% by weight of a polymeric resin, from about 15% by weight to about 70% by weight of a curing agent, and from about 0.10% by weight to about 20% by weight of a fluxing agent. The present invention also further provides an assembly of substrates comprising a lower substrate; a polymeric composition disposed on said lower

substrate; and an upper substrate disposed on said polymeric composition which comprises from about 15% by weight to about 70% by weight of a polymeric resin, from about 15% by weight to about 70% by weight of a curing agent, and from about 0.10% by weight to about 20% by weight of a fluxing agent.

These provisions together with the various ancillary provisions and features which will become apparent to those skilled in the art as the following description proceeds, are attained by the methods and stencils of the present invention, preferred embodiments thereof being shown with reference to the accompanying drawings, by way of example only, wherein:

Brief Description of the Drawings

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Fig. 1 is a vertical sectional view of a pair of spaced large substrates having the liquid polymer of the present invention supported by the lower substrate and in contact with the upper substrate prior to compressing the pair of spaced large substrates and causing the liquid polymer to flow (i.e. to squeeze flow) towards the perimetric edges of the lower and upper substrates;

Fig. 2 is the vertical sectional view of the pair of substrates of Fig. 1 after the substrates are joined together;

Fig. 3 is a top plan view of a lower substrate supporting a plurality of dies, with dispensed liquid polymer in the center of the lower substrate; and

Fig. 4 is a top plan view of a lower substrate supporting a plurality of dies and dispensed liquid polymer disposed on each die.

Detailed Description of Preferred Embodiments of the Invention

Referring in detail now to the drawings, there is seen a substrate assembly, generally illustrated as **10**, including a lower substrate **12**, an upper substrate **14**, and a polymer **16** (e.g., a liquid thermosetting polymer) disposed between lower and upper substrates **12** and **14**. The lower substrate **12** and upper substrate **14** have conductor pads **18** and **20** respectively connected thereto. Solder bumps **19** are bound to conductor pads **18** for assisting in coupling together conductor pads **18** and **20**. Substrates **12** and **14** respectively have edges **12a** and **14a**, and may be any suitable substrate (e.g., semiconductor or conductor substrates) selected from flexible substrates, rigid substrates, circuitized substrates, rigid wafers, circuit boards such as PCB or laminated circuit boards, or the like. The substrates **12** and/or **14** are preferably large substrates having a planar surface area equal to or larger than about thirty-six (36) square inches, such as when substrates **12** and/or **14** are dimensioned from about six (6) inches (or greater) to about six (6) inches (or greater).

The liquid polymer **16** may be dispensed concentrically on the lower substrate **12** and over a center die **24a**, which is surrounded by a plurality of dies **24**, all supported by the lower substrate **12** as best shown in Fig. 3. When the upper substrate **14** is lowered downwardly, the liquid polymer **16** is compressed and squeezed flowed outwardly towards the respective perimetric edges **12a** and **14a** of the lower substrate **12** and the upper substrate **14**. In another embodiment of the present invention, the liquid polymer **16** is superimposed over each of the plurality of dies **24**, as best shown in Fig. 4. When the upper substrate **14** is lowered downwardly, the respective disposed polymers **16** are compressed and squeeze flowed outwardly again towards respective perimetric edges **12a** and **14a** of the lower and upper substrates **12** and **14**, respectively.

Sub B2 Therefore, recapitulating as depicted in Fig. 1, a measured amount of liquid polymer **16** is dispensed at specified location or locations on the lower substrate **12**. The upper substrate **14** is lowered onto the lower substrate **12**, during which it comes in contact with the dispensed polymer **16** and forces the same to move outwards through squeeze flowing. At completion of substrate joining (i.e., when conductor pads **18** and **20** are in contact for reflowing solder bumps **19** as seen in Fig. 2), the joined assembly **10** goes through a heating cycle, well known to those skilled in the art, to form electrically conducting joints **31** (i.e., the joining together of conductor pads **18** and **20** with the assistance of solder bumps **19**) and

Sub B2 to cure the polymer **16**. As shown in Fig. 2, the polymer **16** after curing is an integral part of the joined assembly **10**.

The polymer **16** of the present invention provides a semi-hermetic seal for electrically conducting joints and circuitry on substrate surfaces. The polymer **16** also provides stress relief during service. Temperature fluctuations can lead to stresses from coefficient of thermal expansion mismatch among components in the substrate assembly. The polymer **16** also defines a dielectric layer for isolating electrical signals between substrate circuitry. As previously indicated, the polymer **16** can be dispensed at the center region of the lower substrate **12**, as shown in Fig. 3, or it can be dispensed individually at each die center, as shown in Fig. 4. When dispensed at the substrate center, the polymer **16** flows outward with a single flow front. For multiple point dispensing, a flow front exists for each dispensing location, which may eventually merge and form fewer flow fronts. Air bubbles may be entrapped when flow fronts merge and joining is done at ambient conditions. Joining under a vacuum environment can eliminate entrapped air bubbles. Single point dispensing is useful for smaller substrates, while multiple point dispensing offers better flow control over each die region in joining of very large area substrates.

Suitable material for solder bumps **19** may be metals, or single or multi-phase alloys. The alloys can be binary, ternary, or other higher order compositions. Examples include eutectic Pb/Sn and alloys comprised of In-Sn, Bi-Sn, In-Ag, Sn-Sb, Au-Sn, and Pb-Sn. More specific examples of solders include 52 In/48 Sn, 58 Bi/42 Sn, 97 In/3 Ag, In, 37 Pb/63 Sn, 96.5 Sn/3.5 Ag, 95 Sn/5 Sb, 80 Au/20 Sn, and 90 Pb/10 Sn (described in terms of weight percentages). The solder material may also include any material (e.g., a solder-material fluxing agent) suitable for removing oxides from the solder material for solder bumps **19**. The solder-material fluxing agent may comprise an organic acid, and may be used in combination with a fluxing agent contained in the polymer **16** to remove oxides in and on the soldering material. Organic acids are preferred because they can have relatively high boiling points. Exemplary fluxing agents can include cinnamic acid, succinic acid, gluteric acid, adipic acid, pimelic acid, suberic acid, azelaic acid, adipic acid, sebacic acid, precursors and combinations thereof. The solder-material fluxing agent preferably comprises at least one of cinnamic acid, adipic acid or another acid which functions in a chemically similar manner or has a chemically similar structure. Furthermore, the solder-material fluxing agent can be in

the solder material for solder bumps **19** in any suitable percentage, but can preferably constitute from about 0.1 to about 25 weight percent of the solder material.

The solder-material fluxing agent may be substantially non-volatile (e.g., does not boil or volatize in a substantial manner when the conductive composition is cured). In some embodiments, the solder-material fluxing agent may have a melting point of about 100°C, or more. The boiling or decomposition point of the solder-material fluxing agent, whichever is lower, may be greater than the lowest melting point (e.g., greater than about 10°C) present among conductive particles within solder material for solder bumps **19**. The selection of the particular fluxing agent may depend on the particular conductive material used in the solder material for solder bumps **19**. For example, the solder-material fluxing agent may be cinnamic acid which has a melting point of about 133°C and a boiling point of about 300°C. Suitable conductive particles which can be used with cinnamic acid include particles made of 37 Pb/63 Sn solder, which has a melting temperature of about 183°C.

The polymer **16** of the present invention preferably contains no metals, no conductive materials, and no solder materials (i.e., any of the materials that are contained in solder bumps **19**). The polymer **16** of the present invention preferably also contains no non-conductive particulates, and preferably possesses fluxing capabilities; thus, the polymer **16** includes a fluxing agent. The polymer **16** functions for joining lower and upper substrates **12** and **14**, as well as for providing a polymeric dielectric layer. The polymer **16** further preferably includes very low levels of ionic contaminants and low viscosity (e.g., a viscosity which allows the polymer **16** to flow under the polymeric temperatures of the present invention) so that the polymer **16** may flow around features on both lower and upper substrates **12** and **14**. The polymer **16** preferably will not gel before electrically conductive joints **31** (i.e., solder bumps **19** coupling together conductor pads **18** and **20**) are formed, and after postcure, the polymer **16** exhibits low dielectric constant, high temperature performance, good adhesion to substrate surfaces and components, and low moisture absorption.

The polymer **16** preferably fluxes oxides at metal surfaces, removes water generated from fluxing of oxides, immobilizes ionic species from fluxing of oxides, and allows for modification of coefficient of thermal expansion as needed. The polymer **16** may be disposed on lower substrate **12** by any suitable method, such as by screen printing as described in the book entitled *Microelectronics Packaging Handbook*, copyrighted 1997 by

publisher Chapman & Hall. New York, New York, fully incorporated herein by reference thereto. The polymer **16** comprises a polymeric resin, a curing agent or hardener, and a fluxing agent. More specifically, the polymer **16** comprises, or consists essentially of, or consists of from about 15% by weight to about 70% by weight of a polymeric resin, from about 15% by weight to about 70% by weight of a curing agent, and from about 0.10% by weight to about 20% by weight of a fluxing agent; more preferably from about 25% by weight to about 60% by weight of a polymeric resin, from about 25% by weight to about 60% by weight of a curing agent, and from about 1% by weight to about 15% by weight of a fluxing agent; most preferably from about 40% by weight to about 55% by weight of a polymeric resin, from about 40% by weight to about 55% by weight of a curing agent, and from about 4% by weight to about 12% by weight of a fluxing agent. The polymeric resin may be any suitable polymeric resin that preferably has a temperature (e.g., from about 50°C to about 100°C) that is lower than its curing or setting temperature, which preferably ranges from about 100°C to about 150°C. Preferably, the polymeric resin has a curing temperature (e.g., from about 20°C to about 50°C) higher than the reflow temperature of the soldering material of solder bumps **19**. Also, the polymeric resin may expand when heated, and remain at least partially expanded after cooling. Suitable polymeric resin include epoxy resin made from bisphenol-A and epichlorohydrin, as taught in U.S. Patent No. 5,128,746, incorporated herein by reference thereto.

Additional suitable polymeric resin include, as illustrated in U.S. Patent No. 5,579,573, incorporated herein by reference thereto, thermosetting materials, such as high glass transition anhydride-cured epoxy compositions. More particular suitable thermoset materials include, but are not limited to, one or more compounds selected from group consisting of epoxies and modified epoxies, melamine-formaldehydes, urea formaldehydes, phelonic resins, poly(bis-maleimides), acetylene-terminated BPA resins. IPN polymers, triazine resins, and mixtures thereof. Additional suitable polymeric resin may include high temperature thermoplastic materials such as liquid crystal polyesters (e.g., Xydar™ or Vectra™), poly-(ether ether ketones), or the poly(aryl ether ketones). Further additional suitable thermoplastic materials include, by way of example only, ABS containing resinous materials (ABS/PC,ABS/polysulfone, ABS/PVE), acetals acrylics, alkyds, allylic ethers, cellulosic esters, chlorinated polyalkylene ethers, cyanate, cyanamides, furans, polyalkylene ethers, polyamides (Nylons), polyarylene ethers, polybutadienes, polycarbonates, polyesters,

polyfluorocarbons, polyimides, polyphenylenes, polyphenylene sulfides, polypropylenes, polystyrenes, polysulfones, polyurethanes, polyvinyl acetates, polyvinyl chlorides, polyvinyl chloride/vinylidine chlorides, polyetherimides, polyether ether imides, and the like, and mixtures of any of the foregoing.

The curing agent or hardener may be any suitable curing agent or hardener, such as an amine or an anhydride. The polymeric resin and the curing agent may be a two part resin system such as polyester resins with suitable hardener or curing agents. For example, a commercially available two part resin system is Furane 89303 epoxy, Part A and Part B. Furane 89303 epoxy, Part A, is a bisphenol A-epichlorohydrin type epoxy resin available from the Furane Products Company of Los Angeles, California. Furane 89303 epoxy, Part B, is an anhydride curing agent or hardener also available from the Furane Products Company. It is to be understood that the spirit and scope of the present inventions include other types of two part resin systems which are capable of achieving the desired results within the scope of the invention. The fluxing agent in the polymer **16** assists in the fluxing action for the soldering coupling operation especially if no, or very little, solder-material fluxing agent is admixed in the soldering material of solder bumps **19**. Thus, the fluxing agent in the polymer **16** may be an alternative to using a solder-material fluxing agent in the soldering material, or may be used in combination with a solder-material fluxing agent.

The solder-material fluxing agent in the polymer **16** preferably comprises a phenylacid, more preferably beta phenylacid. It has been discovered that beta phenylacid, especially in combination with an epoxy resin, slows down or retards the curing or hardening of the polymer **16**, leading to longer gel time and allowing the solder material (e.g. 63 Sn/37 Pb) to melt before the polymeric hardens from its initial liquid state. The acid for beta phenylacid is preferably selected from the acid group consisting of acetic, acrylic, crotonic, caproric, valeric, enanthic acid, octylic acid, pelargonic acid, and capric acid. More preferably, the acid for beta phenylacid is selected from the acid group consisting of acetic, acrylic, crotonic, caproic, valeric and enanthic; most preferably from the acid group consisting of acetic, acrylic and crotonic. Particular improved retardation of polymer curing time, leading to longer gel time, is obtained when the fluxing agent is beta-phenylacrylic acid and/or beta-phenylhydroxyacrylic acid.

The polymer **16** is disposed on the lower substrate **12** in a liquid state, and the upper substrate **14** is moved towards the lower substrate **12**, while conductor pads **18**-solder bumps

19 on the upper substrate **14** remain aligned with conductor pads **20** on lower substrate **12**. The liquid polymer **16** is compressed and squeeze flowed outwardly towards the perimetric edges **12a** and **14a** of the lower and upper substrates **12** and **14** by continually moving the upper substrate **14** towards the lower substrate **12** until the solder bumps **19** come in contact with conductor pads **20** to produce the assembly of Fig. 2. The liquid polymer **16** preferably completely encapsulates each of the conductor pads **18**-solder bumps **19**/pads **20**. The fluxing agent in the liquid polymer **16** is in a contacting relationship with solder bumps **19**. The assembly in Fig. 2 is heated, reflowed in a conventional manner, (e.g. to a temperature ranging from about 200°C to about 240°C), causing the fluxing agent in the liquid polymer **16** to be activated and reduce oxides on and in the solder bumps **19**, and allowing alloy coupling of solder bumps **19** to conductor pads **20** and form joints **31** (see Fig. 2). As previously indicated, the fluxing agent in the liquid polymer **16** may be used alone as the sole fluxing agent (no fluxing agent is in the solder material), or the fluxing agent in the liquid polymer **16** may be used in combination with a solder-material fluxing agent in the solder material. During the reflow procedure, the fluxing agent in the liquid polymer **16** also retards or slows down the liquid polymer **16** from curing or hardening, especially when beta-phenylacrylic acid and/or beta-phenylhydroxyacrylic acid is employed as the fluxing agent. Thus, joints **31** are formulated before the liquid polymer **16** has been completely cured or hardened. After joints **31** are formulated, a post curing procedure (e.g., at a temperature ranging from about 100°C to about 180°C) may be required to completely cure the liquid polymer **16**.

Thus, by the practice of embodiments of the present invention there is provided a simple approach to joining of large area substrates. Conventional underfill process for flip chip to substrate joining is limited to very small joining areas (typically 1-inch by 1-inch area or less). Substrate buildup is expensive compared to the simpler approach described in embodiments of this invention. Joining of similar or different substrate materials (i.e., flexible substrates, rigid wafers, and laminated circuit boards) can be performed without substantial process modification. The joining process can be automated for high speed, low cost joining of large area substrates.

While the present invention has been described herein with reference to particular embodiments thereof, a latitude of modification, various changes and substitutions are intended in the foregoing disclosure, and it will be appreciated that in some instances some

features of the invention will be employed without a corresponding use of other features without departing from the scope and spirit of the invention as set forth. Therefore, many modifications may be made to adapt a particular situation or material to the teachings of the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments and equivalents falling within the scope of the appended claims.